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INTERSTELLAR MEDIUM MODEL

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Miss Nancy Vandenberg of the University of Maryland and I developed a model of the ionized part of the interstellar medium based on the low-frequency observations by the Radio Astronomy Explorer (RAE) Satellite with a background of nonthermal radiation. This nonthermal background radiation is caused by synchrotron emission from cosmic ray electrons, and at low frequencies this emission is heavily absorbed by free-free absorption from the residual thermal electrons in the interstellar medium. Hence, by an appropriate model, one can get a handle on parameters relevant to both the thermal and nonthermal components of the interstellar medium.

The observations were taken with the 100° dipole antenna and separated into galactic and extragalactic components by Clark, Brown, and Alexander (Ref. 1). This model was developed using only the separated galactic component.

Our model has a two-dimensional geometry, the plane of the model being perpendicular to the galactic disk and passing through the center and anticenter. Figure 1 is a schematic diagram of the geometry of this model. The directions anticenter (AC), galactic center (GC), and north and south galactic poles (NGP and SGP) are as marked. Cross sections of the three spiral arms in the Sun's local region are shown with the Sun imbedded in the middle spiral arm. The spiral arms are assumed to consist of two components, a warm intercloud region and randomly distributed cold denser clouds. The interarm region is assumed to be similar to the intercloud region with the exception that it is cloud free.

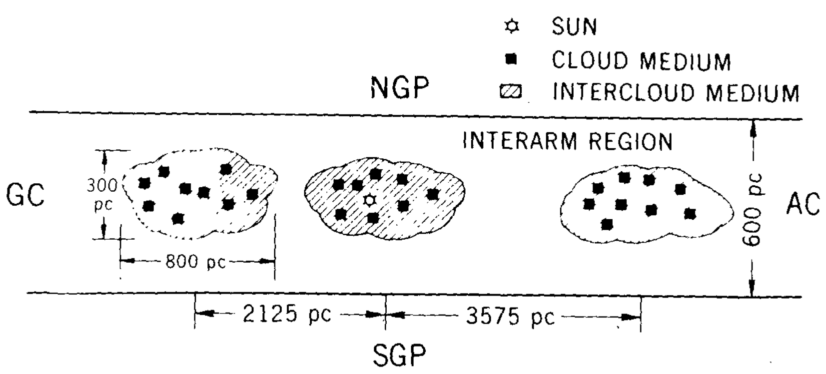

Figure 1–Geometry of the model of the interstellar medium.

At each frequency the model integrated the equation of transfer along lines of sight in a radial grid centered about the Sun. The flux contributions for each frequency were then averaged together to produce the spectra. Integration and averaging were done over a 100° cone comparable to the RAE antenna pattern. The 100° cone was centered on two directions, the north galactic pole and the anticenter.

The best results are shown in Figure 2. Brightness is plotted as a function of frequency, the solid line is the model, the dashed line is the RAE disk component; the error bar is applicable for the entire range shown on the graph. As we can see the two agree pretty closely.

In Table I, our parameters are broken down for the various regions. The first two columns are for the spiral arm, the third for the interarm region.

The volume emissivity for the intercloud and cloud regions was set at 1.0×10^{-39} W m^{-3} Hz^{-1} Sr^{-1} which was determined by Alexander et al. (Ref. 2) from RAE observations. We found that the interarm emissivity had to be 0.16×10^{-39} to fit the observations. This gave an average emissivity of 0.3, which agrees well with the average values extrapolated from higher frequency radio data. The radio of the two emissivities is supported by both theory and observation; and it is quite reasonable to expect a higher emissivity in the spiral arms, where the magnetic field has been compressed.

The intercloud temperatures were found to be 1500 and 2500 K in the two directions. This supports the concept of a thermal gradient away from the plane of the galaxy. The best results were obtained for cloud temperatures between 50 and 150 K. For temperatures less than 50 K the spectrum was flattened too much as the clouds became virtually opaque. For the sake of simplicity we chose the median value of 100 K. The interarm temperatures are not well defined. We can place only the lower limits shown.

The densities shown were fixed throughout the development of the model, and these values were taken from the Hjellming et al. interpretation of observations of the Crab Nebula pulsar (Ref. 3). To get a good fit with the observations we had to have a filling factor of less than 1 percent, which meant there is less than 1 pc of cloud for every 100 pc of intercloud medium.

In conclusion we can state that we have constructed a model using low frequency observations of the heavily absorbed non-thermal background emission that supports the theory of Hjellming et al. of the interstellar medium with an intercloud temperature of approximately 1000 K.

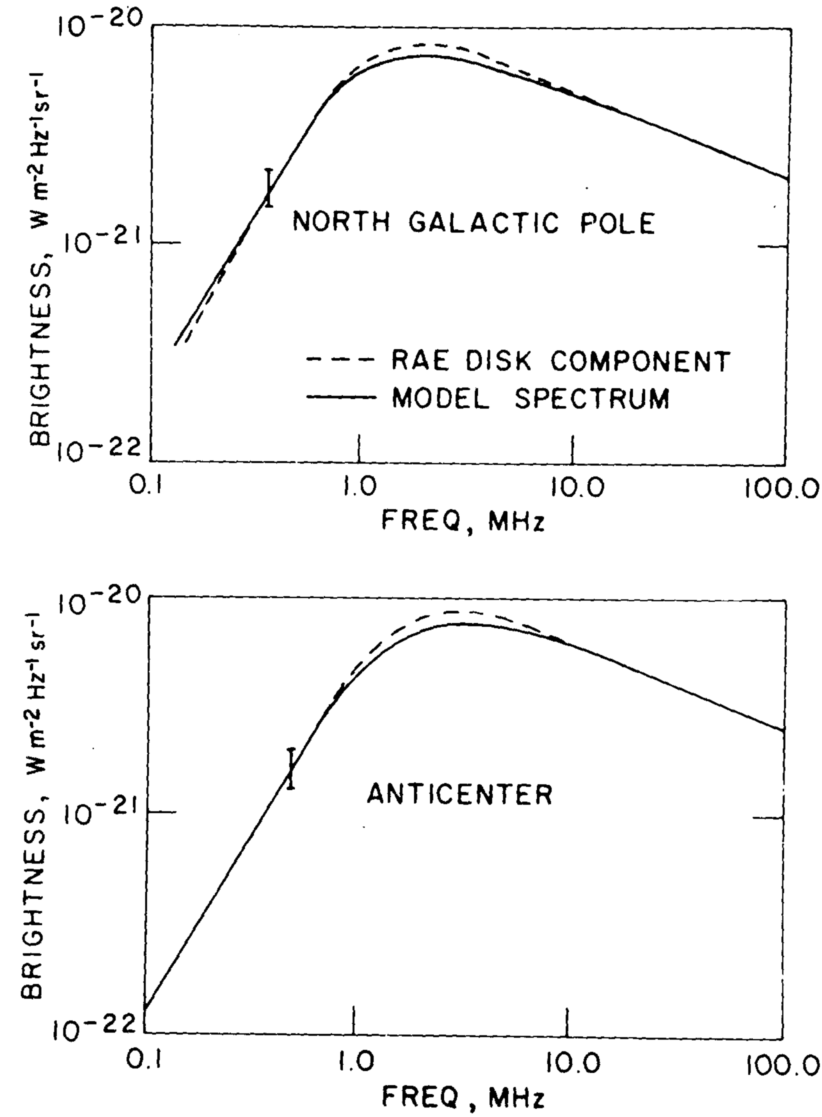

Figure 2–Brightness as a function of frequency for the model (solid line) and the RAE disk component (dashed line).

TABLE I–Summary of the Results

Parameter	Intercloud	Cloud	Interarm
Emissivity, W m^{-3} Hz^{-1} sr^{-1}	1.0×10^{-39}	1.0×10^{-39}	0.16×10^{-39}
Temperature, K			
Anticenter	1500	100	>2500
North Galactic pole	2500	100	>3000
Electron density, cm^{-3}	.028	.044	.028
Filling factor		<1 percent	

While the densities were taken from Hjellming's observations, they are in agreement with densities required by Field et al. (Ref. 4) for their theory of the interstellar medium; but we cannot say that the model can lend support to their theory.

The model also supports the concept of a thermal gradient away from the galactic plane.

CHAIRMAN:

Any questions?

MEMBER OF THE AUDIENCE:

Is this filling factor a linear filling factor or a cubic?

MR. NOVACO:

It is linear.

MEMBER OF THE AUDIENCE:

When the intercloud and the interarm emissivities differ by a factor of 10, why do you get the same densities with the higher temperature in the interarm region?

MR. NOVACO:

The only region in which there is any appreciable absorption from the interarm region is from about 1 to 9 MHz, and by the time we can integrate out to the interarm region, the gas is already essentially transparent and hence we can get no real values for the temperatures. At those frequencies the gas is already essentially transparent. All we can do is place that lower limit. It has to be greater than those values in order to agree with the observations.

MEMBER OF THE AUDIENCE:

What was worrying me is that the density is as great between the arms as in the arms and yet the emissivity is way down.

MR. NOVACO:

Yes, we chose the values of electron densities rather than trying to determine them. Mainly because we have no idea of what value it should be or even what ratio it should be. The emissivity was down in order to agree with the higher frequency data from say 10 to 1000 MHz. If we raised it beyond that, the spectrum was much too bright in those frequencies.

REFERENCES

1. Clark, T. A.; Brown, L. W.; and Alexander, J. K.: Nature, vol. 228, 1970, p. 648.

2. Alexander, J. K.; Brown, L. W.; Clark, T. A.; and Stone, R. G.: Astron. Astrophys., vol. 6, 1970, p. 476.

3. Hjellming, R. M.; Gordon, C. P.; and Gordon, K. J.: Astron. Astrophys., vol. 2, 1969, p. 202.

4. Field, G. B.; Goldsmith, D. W.; and Habing, H. J.: Astrophys. J. Lett., vol. 158, 1969, L73.